BIODYNAMIC TEST INSTRUMENT FOR CHARACTERIZATION OF TISSUES AND BIOMATERIALS

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Abstract-**BioDynamic test instruments provide precise characterization of biomaterials and biological specimens within a closed saline or cell culture media environment. The cell culture incubator-compatible instruments can be used for tension, compression, torsion and pulsatile flow using ElectroForce loading technology and fully-automated computer control and software.**
Keywords - **Mechanical testing, tissue engineering, biomaterials**

I. INTRODUCTION

The objective of this work was to employ the novel design of the BioDynamic testing platform (Fig. 1) to evaluate the mechanical properties of hydrogels and other composite biomaterials. The testing platform allows for continuous test and stimulation in a fully integrated and instrumented configuration by providing material characterization (viscoelastic properties, strength, creep and stress relaxation) within a physiological environment (nutrient flow, pressure loading, pH, dissolved oxygen, and temperature).

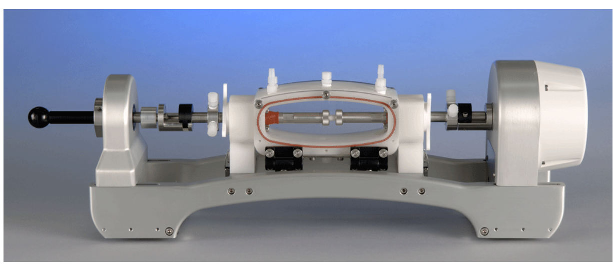

Fig. 1. Compression and perfusion flow through porous platens for orthopaedic specimens.

II. METHODOLOGY

An advanced BioDynamic testing platform has been designed that can be used to evaluate the mechanical properties of tissue-engineered constructs for both cardiovascular and musculoskeletal applications.

The BioDynamic instrument was used to test a variety of specimens to demonstrate its versatility and advanced features with two examples described here. The dynamic mechanical properties of polyvinyl alcohol hydrogels (Cambridge Polymer Group, Boston, MA) were evaluated with our unique computer-controlled moving magnet linear motor that provides load, displacement, strain or pressure profiles. The hydrogel samples were 3-4 mm in diameter and 3-4 mm in height, and testing was performed in compression with a 5 mm displacement transducer and a 250 gram force transducer.

Vascular graft distension with increasing pressure was also evaluated in a BioDynamic instrument using a laser micrometer (Fig. 2). The graft material used (Gel-Del Technologies, Inc., St. Paul, MN) is composed of proteins and polymers fabricated to mimic the viscoelastic properties of native blood vessels. The inner diameter of the grafts used was 3 mm and total length was approximately 30 mm. A laser micrometer was placed over the chamber with the laser beam penetrating the transparent chamber doors and measuring outer diameter (OD) changes with pressure and time.

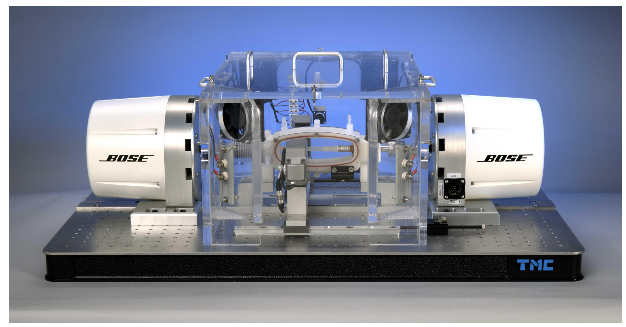

Fig. 2. Tension/compression and pulsatile flow setup for small diameter vascular graft specimens.

III. RESULTS / DISCUSSION

The ability to perform very low force applications is illustrated in Fig. 3. The peak-to-peak loading on the hydrogel was approximately 2 mN with a corresponding peak-to-peak displacement of 28 µm. A distinct linear region was not observed with a displacement ramp as the specimen made a very gradual change in stiffness as a function of % strain. Fig. 4 shows the dynamic mechanical analysis software analysis as a 0.001 N compressive contact force was applied to the specimen. Upon completion of data acquisition, the software calculated the modulus and tan delta for the specimen, which appeared to exhibit resonance between 20 and 100 Hz.

Fig. 5 shows two cycles of a sinusoidal pressure waveform from 0 to 25 mmHg followed by a cycle of pressure increase to 250 mmHg. The diameter response followed the pressure changes very closely throughout the test. After each cycle, OD did not return to its initial value within the test's time frame, indicating potential creep behavior. A cycle of pressure increase from 0 to 295 mmHg is also shown (pressure-diameter curve). The specimen is again exhibiting creep by not returning to its initial diameter over the time frame studied.

A major shortcoming of small diameter vascular grafts is compliance mismatch with native vessels leading to intimal hyperplasia and failure. The resulting pressure-diameter curves shown here can be used for comparison with native

vessels to predict in vivo behavior and patency of vascular substitutes.

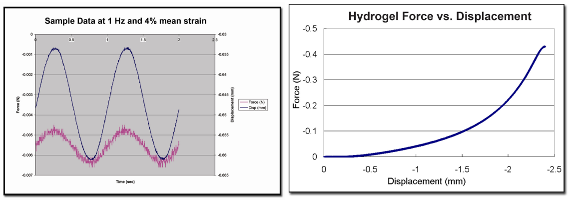

Fig. 3. Dynamic material properties of a soft polyvinyl alcohol hydrogel. (Left) low force application, (right) displacement ramp from contact to 430 mN at a rate of 0.02 mm/s.

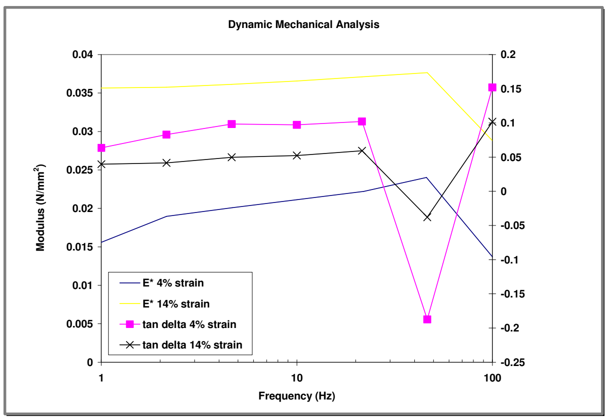

Fig. 4. Hydrogel modulus and tan delta as a function of frequency at various strain levels.

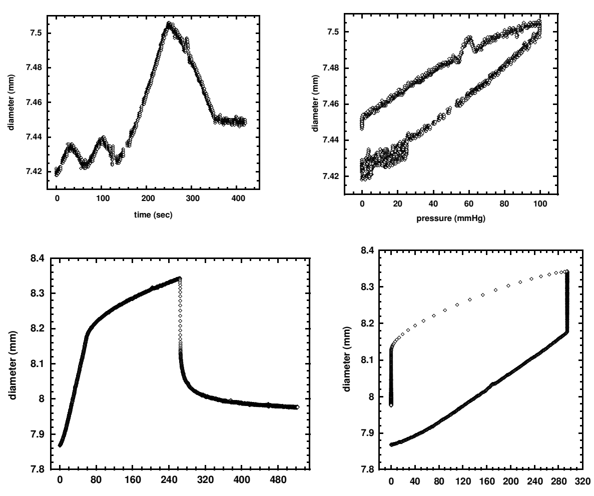

Fig. 5. Vascular graft distension versus time in response to pressure changes and diameter change with pressure. (top panels) pressure was increased to 25 mmHg for two cycles and to 295 mmHg during the third cycle, (bottom panels) linear pressure ramp from 0 to 295 mmHg.

V. Conclusion

The development goal was to create a fully integrated computer-controlled data acquisition and analysis testing system to characterize biomaterials, scaffolds and tissues in a biological environment.

The data obtained with the hydrogels show that the BioDynamic instrument is suitable for evaluating the dynamic properties of soft biomaterials while the results obtained with the vascular graft biomaterial confirmed the biphasic composition of the specimen that is composed of a protein-rich material and synthetic polymers. Preliminary results with hydrogel disks for orthopaedic applications and vascular grafts show that the BioDynamic test instrument is a powerful tool for the integration of biochemical and mechanical stimulation and properties characterization in one system. Multi-specimen design configurations (Fig. 6) allow simultaneous loading and characterization of 4 specimens for higher throughput experimentation. In this instrument, displacement is the same for all four specimens, load is shared among the four, and each chamber has each own perfusion flow loop with either shared or independent reservoir bottles.

Fig. 6. Compression loading and perfusion flow through porous platens for four disc-shaped specimens.